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Field Tests of Elk/Timber Coordination Guidelines

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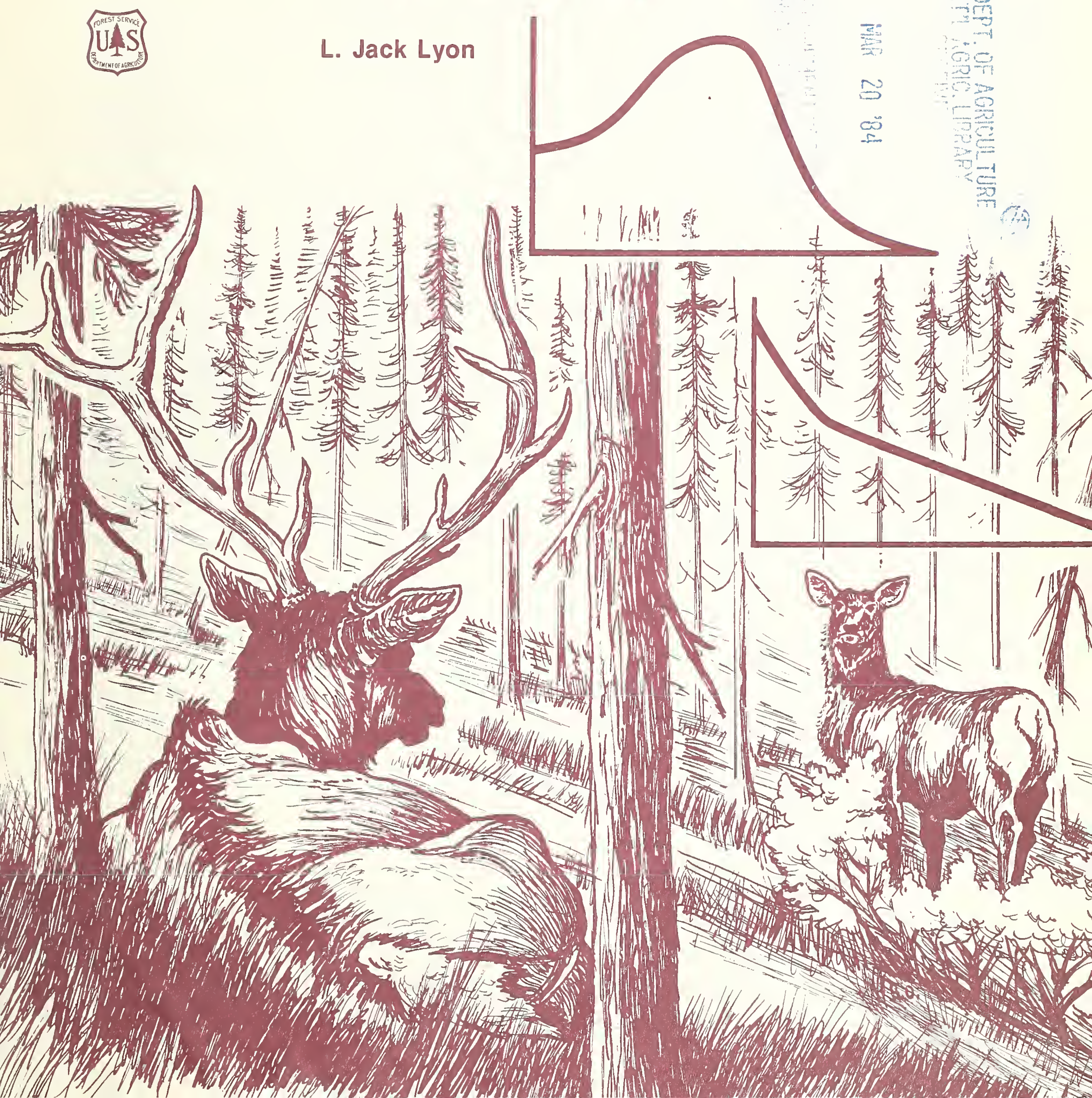

THE AUTHOR

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ACKNOWLEDGMENTS

In all, 46 observers participated in the fieldwork for this study. I am particularly indebted to Thomas O'Neil in 1980 and Leonard Young in 1981. O'Neil successfully completed and defended a master's thesis (O'Neil 1981) based on the first year of data collection.

RESEARCH SUMMARY

During recent years, conceptual models for elk habitat have been widely used as guidelines for coordinating elk habitat management and timber management. The generalized model, consisting of a cover/forage function and a road density function, has been used at the Forest and Regional level for planning required by the Resources Planning Act. In addition, several management biologist teams have developed specific models that recognize local variations in elk behavior. At the present time, despite the wide acceptance and use of the elk/timber guidelines concept, variations in application and calculation methods are common. The many forest biologists and land managers who make decisions based on elk/timber guidelines require confirmed validation of the model.

During the summers of 1980 and 1981, field validation tests were conducted in 11 different areas in Montana and northern Idaho. The objectives of this research were (1) to evaluate several common methods of determining cover/forage ratios, (2) to evaluate several different road-influence models, and (3) to determine the combination of cover/forage function and road model that best describes actual elk selection among different available habitats.

Comparison of on-the-ground cover samples with several indirect methods for determining cover demonstrated that indirect methods generally overestimate actual cover. A reliable indirect method for using photo interpretation (PI types) is presented. Comparison of several different road-influence models demonstrated that predictions and accuracy vary considerably. Acceptable models and precision limits are described. Evaluations of elk habitat quality based on different combinations of cover/forage function and road models were compared to actual habitat selections as indicated by elk pellet group distributions. Findings show that within the range of cover values tested, elk response to habitat quality is primarily determined by road densities. Acceptable road models predict over 50 percent of the variation in habitat use by elk. The best of the cover/forage functions tested improved this prediction on only half the validation areas, and then by less than 10 percent.

In the concluding discussion, it is suggested that a more comprehensive habitat model will be required to provide a valid test of the simple cover/forage functions now being used. Specifically, such a model must account for changes in cover requirements over time.

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INTRODUCTION

Two papers describing preliminary models for coordinating big game habitat management with timber management in the Blue Mountains of Oregon and Washington were presented in 1976 (Black and others 1976; Thomas and others 1976). Soon after, similar models for elk/timber coordination were developed throughout much of the West.

As additional research was completed, habitat models were expanded to include the influence of forest roads and traffic on elk use of the available habitat. By 1979, Thomas and others had developed a more sophisticated model to predict habitat potential as a function of cover/forage ratios and habitat effectiveness as a function of road densities (Thomas and others 1979).

As this work proceeded in Oregon, teams of biologists from State game and fish departments, the USDA Forest Service, and usually from several other agencies, have cooperated in developing elk/timber coordination guidelines for the East-side and Central Zone Forests in Montana, for northern and south-central Idaho, and for the Bitterroot, Kootenai, Bridger-Teton, and other National Forests. Considering the speed with which these models were accepted, modified for local application, and applied in land management, it is not surprising that some guidelines have been interpreted inconsistently. Differences have been further emphasized by continuing research that has modified some guidelines almost annually.

Although there is no valid reason to assume that all elk in all situations will respond to environmental modification in the same way, it was nevertheless considered desirable to conduct a field validation test of existing models to determine what standardization is possible and whether the models do, in fact, predict elk behavior in a variety of environments. Accordingly, field validation tests of elk/timber coordination guidelines were conducted on 11 study areas in western Montana and northern Idaho during the summers of 1980 and 1981. The test hypothesis was that adjacent areas equally available to the same elk would be used by those elk in the proportions predicted by the guidelines.

STUDY AREAS

Study areas were recommended by local biologists within the limitations of the following criteria:

1. Area has a stable elk herd in a productive habitat.
2. Study area can be subdivided into three or four adjacent and topographically similar subunits.
3. All subunits must be equally available to the same elk.
4. No logging or other unusual major disturbance has occurred on the area within the last 2 years.

Areas with recognizable differences in road densities and cover among subunits were preferred. Table 1 and the following narrative briefly describe each of the 11 study areas.

Table 1.—Summary descriptions of 11 study areas

Area	Sub-units	Acres	Hectares	Forest	Average elevation		Trees[1]
					Feet	*m*	
Skalkaho	4	8,774	3 553	Bitterroot	7,600	2 317	ABLA-PICO
Blue Mountain	3	10,870	4 402	Lolo	5,200	1 585	PSME
Jim Creek	4	8,978	3 636	Flathead	4,800	1 463	THPL-ABLA
Beaver	3	10,701	4 334	Kootenai	4,700	1 433	TSME-ABLA
Petty	4	12,901	5 225	Lolo	5,300	1 615	PSME-PICO
Bateman	3	8,666	3 510	Lolo	5,400	1 646	PSME
Hyalite	4	16,843	6 821	Gallatin	7,100	2 164	ABLA-PICO
Judith	4	15,445	6 255	Lewis & Clark	6,800	2 073	ABLA-PICO
Red Ives	3	7,844	3 177	St. Joe	5,300	1 615	TSME-ABLA
Canyon	3	8,547	3 462	Clearwater	4,500	1 372	THPL-ABGR
Newsome	3	8,165	3 307	Nezperce	5,200	1 585	THPL-TSHE

[1]Although habitat types (Pfister and others 1977) were recorded, the most important tree species provide a broader description for this table: ABLA, *Abies lasiocarpa;* PICO, *Pinus contorta;* PSME, *Pseudotsuga menziesii;* THPL, *Thuja plicata;* TSHE, *Tsuga heterophylla*; TSME, *Tsuga mertensiana*; ABGR, *Abies grandis.*

Skalkaho.—The Skalkaho study area is located 15 miles (24 km) east of Hamilton, Mont., in the Sapphire Mountains. It lies entirely within the Skalkaho Game Preserve, which is closed to big game hunting. Logging has taken place in two of the subunits. The other two subunits are completely unroaded.

Blue Mountain.—The Blue Mountain area is 7 miles (11 km) west of Missoula, Mont., in an area that has been moderately to heavily logged. All three subunits are accessible in some degree by way of old logging roads.

Jim Creek.—Jim Lake, located in the southernmost subunit of the Jim Creek area, is a popular and easily accessible recreation site 5 miles (8 km) northwest of Condon, Mont. All four subunits border the Mission Mountain Wilderness, and logging has taken place in three of the subunits.

Beaver.—This study area is located at the headwaters of Big Beaver Creek, 14 miles (23 km) southwest of Trout Creek, Mont. All three subunits have been logged to some degree.

Petty.—This study area consists of four nearly parallel drainages to Petty Creek. It lies 27 miles (43 km) west of Missoula, Mont. Three drainages have been logged in recent years; the fourth is mostly undisturbed although easily reached from existing ridgeline roads.

Bateman.—The Bateman study area runs from Burnt Mountain to Bateman Creek on a north-facing aspect above the Clark Fork River, 24 miles (39 km) east of Missoula, Mont. Three subunits range from heavily logged and roaded to inaccessible, although all three have been logged.

Hyalite.—The four subunits of the Hyalite study area include both sides of Hyalite Canyon about 8 miles (13 km) south of Bozeman, Mont. All four subunits have been logged, but many of the logging roads are closed to vehicular traffic and much of the recreational use occurs near the valley bottom.

Judith.—The four subunits of the Judith study area lie on both sides of Deadhorse Creek in the Little Belt Mountains about 25 miles (40 km) northeast of White Sulphur Springs, Mont. All four subunits have been logged, and road densities are relatively high throughout the area.

Red Ives.—The Red Ives study area is located 50 miles (80 km) east of St. Maries, Idaho, on the divide between the St. Joe and Clearwater Rivers. Two of the subunits have been logged, and all three are accessible from a road running along the divide.

Canyon.—This study area is located 10 miles (16 km) north of the junction of the Lochsa and Selway Rivers in northern Idaho. Two of the three subunits have been logged, one very heavily, and the third is accessible only from a ridgeline road.

Newsome.—Although four subunits were sampled on this study area 15 miles (24 km) northwest of Elk City, Idaho, only three proved to be comparable. Of these, two have been logged and one is essentially undisturbed.

DATA COLLECTION

Within each subunit, 5 to 15 miles (8 to 24 km) of belt transect were sampled to determine elk use. Observers walked a designated course, usually on contour at a specified elevation, and recorded all pellet groups in an area 2 feet (0.6 m) on either side of the path. Pellet groups were classified as fresh, new, old, or very old on the basis of color and stage of deterioration. Groups were recorded by age class within variable length segments along the transect. Segments were separated at any point where a change in aspect or stand condition was noted. Observers sampled each subunit on at least two transects separated by 200 to 500 vertical feet (61 to 152 m).

In addition to recording pellet groups, observers evaluated the elk habitat on each segment and classified it as hiding cover; thermal cover; forested forage; open forage; or nonhabitat, such as rockslides and open water.

After the collection of field data, each area was mapped using aerial photographs and Forest Service photo interpretation (PI) maps. PI types were planimetered and mileages measured for primary, secondary, and primitive roads within each subunit. Comparative data for the 11 study areas are presented in table 2.

PRELIMINARY ANALYSES

Elk Use

Estimates of elk use in each of the subunits were derived by calculating the total area sampled on transects and dividing into the sum of the pellet groups recorded. All pellet groups judged to be very old were deleted from this analysis. Densities ranged from a low of 1.7 groups per acre (0.7/ha) in the Jim Lake subunit of the Jim Creek study area to a high of 179.2 (72.6/ha) in the Falls Creek subunit of the Skalkaho (table 2).

Statistical evaluation of differences among transects, observers, and subunits requires an estimate of variance within samples. This estimate was calculated by treating each transect segment as a single observation, even though segments were not of equal length. The resulting analysis overrepresents short segments in the calculation means, but variance estimates are considered representative of true variance for sample means (table 3).

Observers

In all, 46 observers participated in this study; however, only 8 observers walked more than 2 transects and only 3 walked more than 10 transects. In most cases, it was necessary to assume that variations among observers represented actual variation among transects. One observer, however, recorded only a single pellet group on a transect in the Hyalite study area, and since

Table 2.—Comparative data for 38 subunits in 11 study areas[1]

Study area and subunit	Acres	Transect miles	Pellet groups[2]			Pellet groups per acre	Miles of road			Miles per section[3]	
										Total	Rated
Skalkaho											
Falls Creek	2,813	11.4	68	501	425	179.2	0	0	0	0	0
Little Burnt	2,103	10.2	25	428	350	170.0	0	0	0	0	0
Dam	1,888	8.7	15	209	234	108.8	0	5.7	0	1.9	1.4
Crooked	1,971	7.4	17	146	161	90.9	3.1	0	1.4	1.5	1.0
Blue Mountain											
Woodman	3,720	14.0	12	52	44	15.9	0	3.8	2.9	1.2	.5
Sleeman	4,074	11.7	8	27	52	15.4	1.1	2.4	0	.5	.4
Camp	3,077	10.6	3	11	13	5.3	0	5.9	2.7	1.8	.9
Jim Creek											
Piper Crow	1,498	4.7	2	13	9	10.4	1.3	0	0	.6	.6
Moore	2,751	5.7	4	9	12	9.1	2.9	0	0	.7	.7
Lookout	1,979	5.4	4	2	10	6.1	1.0	0	0	.3	.3
Jim Lake	2,750	6.0	0	3	2	1.7	5.8	7.3	2.5	3.6	2.6
Beaver											
South Dixie	4,497	6.6	12	71	54	43.4	5.8	1.1	.5	1.1	.9
Green	3,005	9.5	28	54	73	33.8	9.8	3.7	.5	3.0	2.6
Dry Gulch	3,199	7.6	8	42	39	24.3	4.3	1.8	.9	1.4	1.1
Petty											
Eds Creek	4,311	13.1	6	112	141	28.0	1.6	4.0	0	.8	.6
Johns	2,264	8.2	14	44	44	25.7	.9	1.0	.9	.8	.5
Gus Creek	2,424	9.0	0	21	84	24.1	0	2.0	0	.5	.4
South Fork	3,904	14.8	3	63	78	20.1	2.4	.3	.5	.5	.4
Bateman											
Tyler	2,593	9.2	3	10	43	12.5	.7	1.9	0	.6	.5
Bateman	2,853	13.7	3	15	54	11.5	0	4.0	2.8	1.5	.7
Burnt	3,221	8.9	0	5	27	7.4	12.1	3.3	12.0	5.4	3.0
Hyalite											
Chisholm	4,554	10.2	8	37	72	23.8	1.9	0	1.6	.5	.3
Buckskin	4,007	10.7	3	10	39	17.1	1.2	4.7	3.5	1.5	.7
Window Rock	4,630	10.7	8	21	25	10.5	2.0	4.0	4.3	1.4	.7
Langhor	3,652	10.0	5	22	14	8.5	2.1	12.3	2.3	2.9	1.9
Judith											
Cross	4,233	11.5	6	70	89	29.7	4.2	2.3	.5	1.1	.9
Bighill	3,775	10.2	8	144	152	62.5	5.6	3.9	1.2	1.8	1.4
Smith	3,720	9.4	3	82	165	54.9	5.2	3.8	.5	1.6	1.4
Clyde	3,717	10.4	8	39	40	17.3	8.8	1.8	0	1.8	1.7
Red Ives											
Buck Light	3,421	14.4	1	21	53	10.7	5.2	.5	0	1.1	1.0
Hoodoo	1,757	6.4	2	11	13	8.4	5.5	.6	5.9	4.4	2.3
Spotted	2,666	11.9	2	17	11	5.2	4.1	3.0	1.6	2.1	1.5
Canyon											
Middle	2,747	12.5	4	63	105	28.5	3.1	0	0	.7	.7
Deadman	2,392	12.0	3	29	64	16.5	6.0	1.0	0	1.9	1.8
Canyon	3,409	10.6	1	7	23	6.0	15.4	5.1	0	3.8	3.6
Newsome											
Baldy	2,771	10.2	4	109	143	53.0	0	3.7	1.0	1.1	.6
Pilot	2,113	7.0	6	20	116	42.1	0	4.1	0	1.2	.9
New China	3,280	13.0	22	71	97	30.2	2.0	2.6	1.4	1.2	.8

[1]Metric conversion factors: acres X 0.405 = hectares; miles X 1.609 = km; miles/section X 0.621 = km/km^2.
[2]Pellet groups: fresh, new, old.
[3]Miles per section: total = primary + secondary + primitive; rated = primary + 0.7 secondary + 0.05 primitive.

Table 3.—Variance analyses for differences among transects, among subunits, and among transects within subunits (asterisk indicates probability F<0.05)

Area	Transects No.	Transects F	Subunits No.	Subunits F	Transects within subunits[1]
Skalkaho	12	5.32*	4	4.91*	2
Blue Mountain	9	5.22*	3	4.58*	1
Jim Creek	8	4.25*	4	7.86*	None
Beaver[2]	8	1.52*	3	4.25*	None
Petty	11	5.84*	4	1.83	2
Bateman	7	3.88*	3	.78	1
Hyalite	8	5.37*	4	5.65*	2
Judith	12	2.83*	4	2.52*	2
Red Ives	12	1.22	3	1.51	None
Canyon	10	6.51*	3	11.18*	1
Newsome	9	4.08*	3	2.69*	1

[1]Number of subunits in which significant differences among transects were detected.
[2]Two transects deleted because of significant winter range use.

two other observers on adjacent transects averaged 17 pellet groups per acre (6.9/ha), this data set was not used. In addition, one observer on the Petty study area consistently recorded two to three times as many pellet groups as observers on nearby transects. In this case, since results of subsequent analyses were similar using adjusted or unadjusted data, the unadjusted records were used.

Transects and Subunits

In preliminary analyses, significant differences among transects were detected on all but the Red Ives study area (table 3). There were only three study areas in which significant differences were not detected among subunits, and three with no significant differences among transects within subunits. For the most part, these differences were assumed to indicate differences in elk distribution that were related to habitat quality. The initial analysis, however, also demonstrated strong elk responses that were unrelated to the fairly simplistic model of habitat quality tested in this study. In two cases where elk response to extraneous factors could be clearly identified, data were either deleted or restructured.

In the Judith study area, for example, the selection criterion requiring all subunits to be equally available to the same elk was not satisfied. Two subunits north of the Judith River had 2.45 times as much elk use as the two subunits south of the river. Pellet group density estimates were adjusted upward in the two southern subunits to reflect this difference. In the South Dixie subunit of the Beaver Creek study area, five transects demonstrated a strong gradient to high winter range use at lower elevations. In this subunit, data from the two low-elevation transects were deleted from further analysis.

Cover/Forage

Preliminary analyses also required calculation of cover/forage ratios in each of the subunits. Determining cover values has been particularly difficult because management biologists rarely have the luxury of conducting on-the-ground sampling as done in this study. Instead, cover values are usually derived from photo interpretation data or timber stand inventories. Stand inventories were not available for this study, so analysis was limited to evaluation of PI types.

For each study area, field observations in PI types were summarized to obtain locally applicable conversion percentages. On the Judith study area, for example, observers encountered PI type 11 113 times and classified it as cover 51 times, which meant 45.1 percent of the PI 11 acreage was considered cover.

In addition to calculations based on individual study area data, two indirect rules for determining cover were developed and tested. Observations from all Idaho study areas were combined in one set, and observations from the more xeric lodgepole and Douglas-fir types in Montana in a second set, to obtain, respectively, the Idaho and Montana Rules (table 4). And, finally, several arbitrary assignment rules that assume certain PI types to be cover were evaluated. A complete presentation and discussion of these methods is not necessary here because most were found to be unsatisfactory. Any arbitrary assignment rule that classifies PI 11 and 14 as cover will overestimate cover values in most areas.

Best estimates were derived by using the Montana Rule for more xeric study areas and the Idaho Rule for more mesic study areas. Using the percentage conversions presented in table 4, the average cover estimate for Montana Rule areas was 46.5 (± 1.0), n = 22 and for Idaho Rule areas, 66.9 (± 2.2), n = 17. These estimates compare to observer averages of 46.2 (± 2.8) and 66.7 (± 2.7). Table 5 presents cover values for individual subunits.

Table 4.—Average percentage cover[1] for PI types, Montana Rule, and Idaho Rule

PI type	Montana Rule			Idaho Rule		
	Cover	Hiding/thermal[2]		Cover	Hiding/thermal	
11	58	41	17	82	51	31
12	38	29	9	85	65	20
13	31	22	9	46	46	0
14	63	45	18	79	64	15
15	45	45	0	64	39	25
16	34	28	6	58	53	5
17	57	33	24	65	52	13
18	39	34	5	50	45	5
19	38	30	8	50	50	0
20	30	20	10	25	25	0
21	36	16	20	30	30	0
[3]22	30	30	0	30	30	0
23	50	50	0	50	50	0
24	30			30		
25	50			30		
26	15			15		
27	53			50		
28	33			30		
29	12			15		
30	22			20		
31	36			35		
32	23			21		
33	7			4		
40	38			40		
60	14			14		
91	15			15		
93	10			10		

[1]Based on the percentage of times reported as cover in field observations. For a few PI types, values are arbitrarily assigned because of small sample sizes.
[2]Hiding/thermal percentages are indicated for those PI types in which some trees are tall enough to satisfy the thermal cover definition (over 40 feet [12.2 m]).
[3]Any cover recorded in PI types 22-93 was considered to be hiding cover.

Table 5.—Cover percentages in subunits as determined by observers on the ground and by indirect estimates based on Montana and Idaho observer averages applied to PI types

Area	Observers				State PI rules			
Skalkaho	47.1	52.1	41.5	40.0	45.8	49.7	40.3	39.4
Blue Mountain	55.4	54.5	52.8		48.6	48.7	51.2	
Jim Creek	75.8	85.7	70.6	49.6	70.5	78.8	64.6	47.8
Beaver	67.8	68.7	57.9		64.2	65.0	55.8	
Petty	64.7	61.6	61.5	46.8	55.0	54.1	53.1	42.4
Bateman	18.8	20.5	17.2		46.5	45.3	39.8	
Hyalite	52.3	53.0	55.7	53.5	40.0	46.1	42.9	46.0
Judith	45.6	37.8	38.3	44.8	52.0	43.1	43.1	50.0
Red Ives	61.0	61.5	59.3		67.4	71.3	70.9	
Canyon	76.5	68.0	45.2		73.5	71.0	48.5	
Newsome	66.2	67.0	87.9		69.9	68.2	78.0	

Examination of table 5 shows that the State PI rules usually produce estimates of cover within 10 percent of on-the-ground sampling estimates. Only the Bateman study area deviated greatly. Nevertheless, it is clear that local sampling should supplement and modify indirect conversion of cover percentages. In particular, PI types 11 and 14 should be sampled where they constitute a large proportion of available habitat.

VALIDATION ANALYSES

Following the preliminary summary analyses, cover and road density data were used as indicated in a generalized model of the elk habitat guidelines to predict elk habitat quality for each subunit. All analyses were duplicated using the cover values determined by observers and the cover values derived from State PI rules. There were only minor differences in results from these two analyses, but because management biologists are almost always restricted to indirect methods for determining cover, only the State PI analysis is presented in this report.

Habitat Potential

According to the hypothesis proposed by Black and others (1976), the relationship between cover and foraging areas determines habitat potential for elk. Cover is defined as: thermal cover when 40 feet (12.2 m) tall with average crown canopy >70 percent; or hiding cover when it will hide 90 percent of an elk at <200 feet (61 m). Forage is defined as: forested forage when forested, but not classified as cover; or open forage when the area is without trees. Both thermal cover and hiding cover are required by elk, and all areas not classified as cover become foraging areas by default. A forest area with a cover surplus can be improved for elk if cover is removed until an optimum ratio between cover and foraging area is obtained. Continued removal of cover, however, leads to a precipitous decline in habitat potential.

The initial versions of habitat management guidelines proposed a different function for each of several land types, habitat types, or both. More recent versions assume that elk movement between cover and forage areas adequately integrates available habitat as long as the size and spacing of different stands are satisfactory. For this study, evaluation was concentrated on a "Single c/f" function (fig. 1) with a theoretical potential for doubling habitat quality as cover is reduced from 100 to 40 percent and an equivalent loss in quality as cover declines from 40 to 25 percent. Several other cover/forage functions were tested, and I also tested a "No c/f" function under which all cover values were considered equally acceptable.

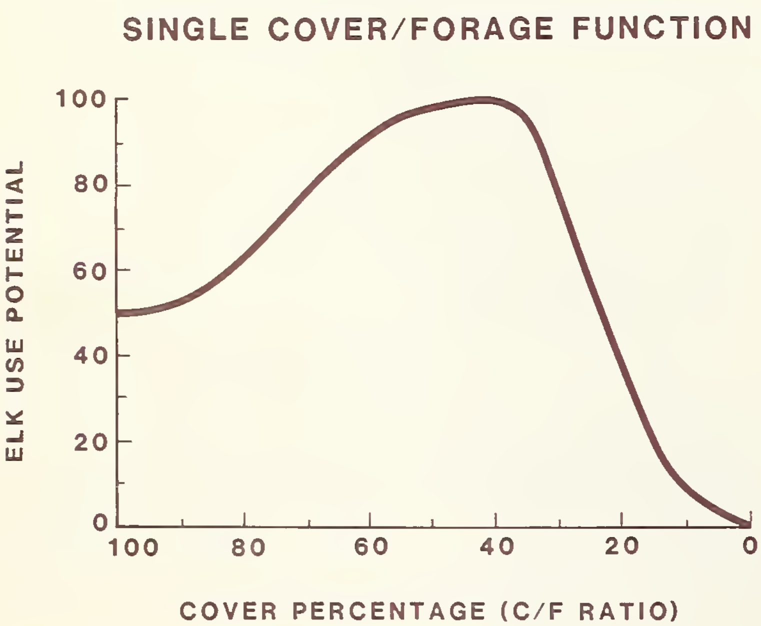

Figure 1.—Single cover/forage function.

Habitat Effectiveness (Roads)

Declines in elk use of habitat adjacent to open forest roads have been documented repeatedly (Hershey and Leege 1976; Lyon 1979; Marcum 1976; Perry and Overly 1976, 1977; Rost and Bailey 1974, 1979; Ward 1976), but only three models for evaluating the influence of road densities in elk habitat have been published (Thomas and others 1979; Lyon 1979, 1983). These models, although derived from basically similar data, differ significantly in concept and output.

The Perry-Overly model (Thomas and others 1979) contains three nonlinear functions: one for primary roads, another for secondary roads, and a third for primitive roads. In 1979, I published a cover/road model with four linear functions: one for each of four cover densities. More recently (Lyon 1983), I have used the same data to develop a model with a single nonlinear function.

In this study, I evaluated these road models, several other unpublished road models, and some alternative methods of calculating road densities. The majority of these evaluations produced unsatisfactory results, and only the published road models are evaluated here.

1. Perry-Overly (Thomas and others 1979) (fig. 2). This model uses three nonlinear functions relating the independent influences of primary, secondary, and primitive roads on habitat effectiveness for elk. The calculation method, described in Agriculture Handbook 553, assumes that declines in effectiveness are additive.

2. Linear Cover/Road-A (Lyon 1979) (fig. 3). This model uses four linear functions relating losses in habitat effectiveness to cover availability in four categories. Since the published model assumes all roads to be of the same type, the initial evaluation was calculated with road densities based on the sum of primary and secondary roads.

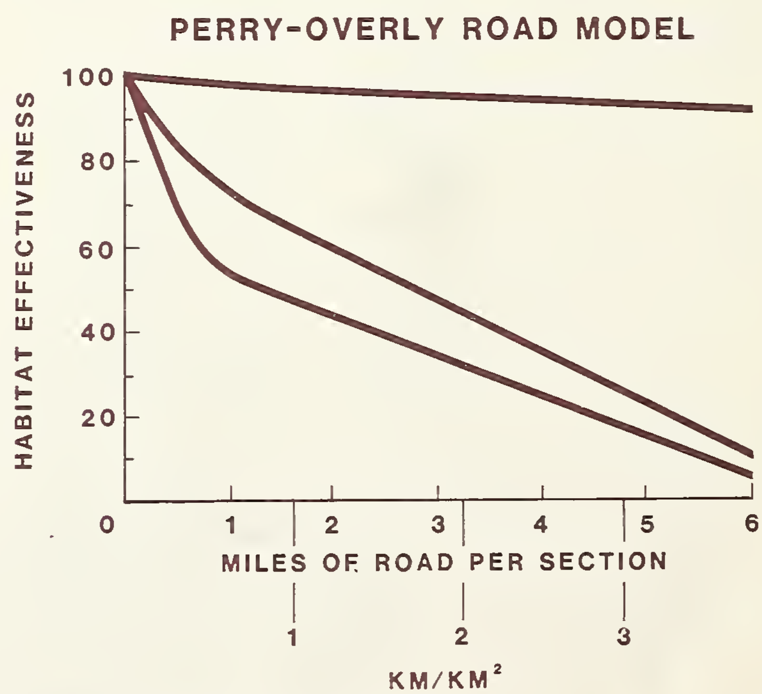

Figure 2.—Perry-Overly road model.

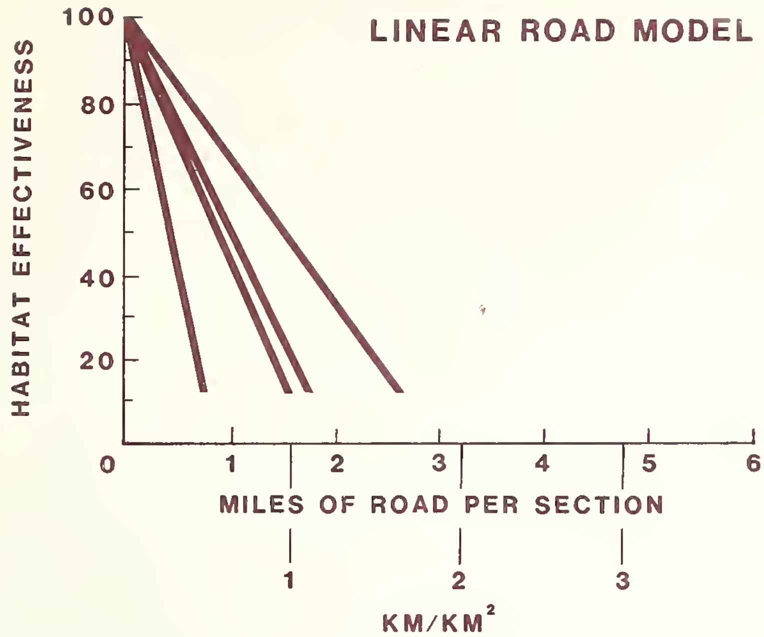

Figure 3.— Linear road model.

3. Linear Cover/Road-B. A second calculation with this model scaled road densities in proportions suggested by the Perry-Overly model: 1.00 for primary roads, 0.70 for secondary roads, and 0.05 for primitive roads.

4. Single Function-A (Lyon 1983) (fig. 4). This model projects road density influences as a single nonlinear function of the same shape as the Perry-Overly functions. In the initial calculation, road densities were based on the sum of primary and secondary roads.

5. Single Function-B. A second calculation with this model scaled road densities in proportions suggested by the Perry-Overly model.

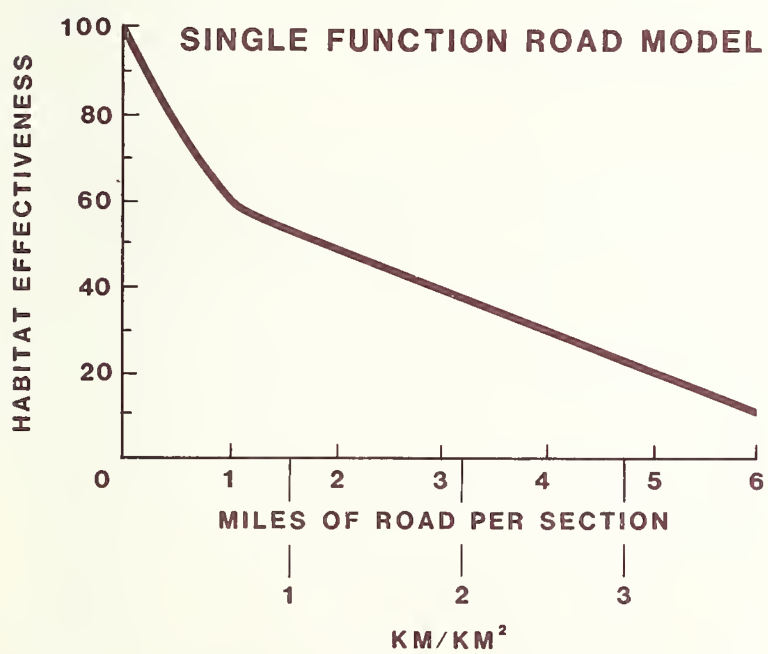

Figure 4.—Single function road model.

Habitat Evaluation

After determination of a coefficient for habitat potential (cover/forage), and a coefficient for habitat effectiveness (roads), the habitat value for each subunit was estimated as the product of the two coefficients. The test hypothesis assumes that elk use of the study area, as estimated by the sum of all pellet groups recorded, should be distributed among subunits in the proportions indicated by the habitat values. An example of a validation test is presented in table 6.

In this example, cover ranged from 40.0 to 46.1 percent and road densities from 0.28 to 1.90 miles per section (0.17 to 1.18 km/km^2) among the four subunits. Coefficients for habitat potential were all close to 1.00, but coefficients for habitat effectiveness ranged from 0.85 on the least roaded subunit to less than 0.50 in the heavily roaded subunit. The products of the cover and road coefficients provide estimates of relative habitat value ranging from 0.49 to 0.85.

The sum of all pellet groups in the study area, taken to represent the elk population, was distributed among subunits in proportions indicated by habitat value coefficients. For this example, predicted pellet-group density came within 2 ½ pellet groups per acre (1.0/ha) for two subunits and within 5 per acre (2.0/ha) for the other two subunits. The mean square deviation, or variance, among the four estimates tests precision. Had the predictions agreed with measured elk use, variance would have been zero.

To complete the evaluation and allow for comparison among models, the calculated variance was divided by the average pellet group density on each study area. This standardized variance (SV = variance/mean) is comparable for all study areas even where actual elk populations are far different. SV was selected instead of the more familiar coefficient of variation (CV = standard deviation/mean) because the CV tended to overemphasize estimates from areas with small elk populations.

In all but two study areas, at least one combination of a cover/forage function and a road model produced a deviation variance smaller than the mean (SV < 1). No tested combination produced SV < 1 on more than six areas. Table 7 presents average standardized variances for the Single c/f and No c/f functions and for three of the many road models tested. None of the other tests gave results as precise as the best of these.

The smallest average SV in table 7 has a P:0.05 confidence interval of 0.75 to 1.97. Calculation of similar confidence intervals for other SV averages confirms that estimates of habitat value using the linear cover/road model are less precise than estimates made with other road models. There were no significant differences between estimates based on the Perry-Overly and single function road models. Nevertheless, the Perry-Overly model should not be used because, in all combinations, it estimates greater losses in habitat effectiveness when primary and secondary roads are evaluated separately than when an equivalent density of primary roads is evaluated alone.

Table 6.—Representative validation test. Hyalite study area, "single c/f" and "single function-B" models with road density based on primary + 0.7 secondary + 0.05 primitive

Item	Subunit							
	Chisholm		Buckskin		Window Rock		Langhor	
Acres (hectares)	4,553.8	(1 844.3)	4,007.3	(1 623.0)	4,629.7	(1 875.0)	3,652.4	(1 479.2)
Percent cover	40.0		46.1		42.9		46.0	
Road miles (km)								
Primary	1.9	(3.1)	1.2	(1.9)	2.0	(3.2)	2.1	(3.4)
Secondary	0		4.7	(7.6)	4.0	(6.4)	12.3	(19.8)
Primitive	1.6	(2.6)	3.5	(5.6)	4.3	(6.9)	2.3	(3.7)
c/f coefficient	1.000		0.992		0.998		0.992	
Road coefficient	.851		.671		.687		.496	
Habitat value	.851		.665		.686		.492	
PGA actual (group/ha)	23.75	(9.6)	17.09	(6.9)	10.46	(4.2)	8.48	(3.4)
PGA estimated	18.93	(7.7)	14.79	(6.0)	15.25	(6.2)	10.95	(4.4)
	4.82	(2.0)	2.30	(.9)	4.79	(1.9)	2.47	(1.0)

Mean square = 19.19, standardized = 1.26

Table 7.—Average standardized mean square deviation and standard errors, 2 cover/forage functions, 3 road models, and 2 calculation methods[1] on 11 study areas

Road model	Cover/forage function	
	Single c/f	No c/f
Perry-Overly	1.67 (0.728)	1.53 (0.623)
Linear cover/road-A	5.80 (1.483)	5.62 (1.265)
Linear cover/road-B	5.21 (1.268)	5.16 (1.140)
Single function-A	1.60 (.384)	1.45 (.307)
Single function-B	1.56 (.409)	1.36 (.273)

[1]A, when road density = primary + secondary; B, when road density = primary + 0.7 secondary + 0.05 primitive.

Initially, the results in table 7 seemed to provide an evaluation of relative importance for cover/forage functions and road models in the habitat management guidelines. The road model alone (No c/f) predicted about 56 percent of the variation in elk use among subunits, and the addition of the cover/forage curve failed to consistently improve predictions. In retrospect, the apparent failure of the cover/forage function should have been anticipated because a majority of subunits examined in this study had cover percentages between 40 and 55 percent—a range where little difference in elk response could be expected. Moreover, cover values among subunits ranged more than 10 percent in only four of the study areas. Thus, this study was almost certain to provide a more powerful test of road effects than of cover/forage influences.

Examination of SV for individual study areas (table 8) reveals that the Single c/f did improve predictions on half the study areas but failed on the other half. For the six areas where an improvement was recorded, $r^2 = 0.63$ ($n = 20$ subunits); for the remaining five areas $r^2 = 0.19$ ($n = 18$ subunits). As a result of this observation, predictions for all study areas were examined for possible relationships correlated with cover, roads, habitat diversity (Simpson's diversity index), disturbances, seasonal habitat selection, and elk population levels.

Considering the relatively narrow range of cover values tested in most of the study areas, it was expected that the cover/forage function might have the greatest influence on those study areas with the greatest range of cover values. This did not prove to be the case. Instead, the predictions improved most on study areas where cover among subunits was most similar. Nor was there any indication that geographic location, timing of fieldwork, elk population levels, or habitat diversity contributed in any way to the failure of the c/f function to consistently improve predictions made with the road model. The only strong relationship discovered indicated that for the five areas in which the c/f function failed to improve predictions, elk use of subunits with the heaviest available cover was greater than use predicted by the model. Subunits with relatively less cover were avoided.

Table 8.—Standardized mean square deviations, two cover/forage functions, and the single function-B road model on 11 study areas

Study area	Cover/forage function	
	Single c/f	No c/f
Skalkaho	0.81	0.84
Blue Mountain	1.62	1.68
Jim Creek	2.26	1.36
Beaver	4.19	3.04
Petty	1.00	.82
Bateman	.03	.04
Hyalite	1.26	1.27
Judith	.50	.49
Red Ives	.73	.82
Canyon	3.91	2.01
Newsome	.90	2.56
Average	1.56	1.36
Improved, 6 areas	.89	1.20
Not improved, 5 areas	2.37	1.54

Any major local disturbance requiring elk to seek the best available cover should have been detected during fieldwork. Observers, however, recorded no such disturbances. During the study a pole sale was activated in the Crooked subunit of the Skalkaho area; there were active timber sales adjacent to the Canyon, Petty, and Blue Mountain study areas; and the Newsome area was open to year-round hunting by the Nez Perce Indians. Nevertheless, only one of these areas is among the five for which the cover/forage function failed to improve the prediction. In those five areas, there was no consistent pattern of woodcutting, active timber sales, or other disturbance that might help to explain the elk selection for heavier cover.

DISCUSSION

Although there was no apparent relationship between elk selections for heavy cover and the time at which fieldwork was conducted, it would not be surprising if some undetected relationship did, in fact, exist. Fieldwork for this study was completed over a period of two summers, and it is possible that the variation observed simply demonstrates normal changes in seasonal habitat requirements. Skovlin (1982) and several others have described a strong seasonal gradient in habitat use by elk: through late June, open grasslands are the primary feeding areas and use of hiding cover is minimal. By August, warmer temperatures, drying forage, and insects produce a habitat shift to forest cover. Thus, even if the cover/forage function does describe an average habitat use pattern, it does not satisfactorily describe the temporal relationships.

CONCLUSIONS

Results of these field tests suggest that the road-density model is a very powerful tool for evaluating and manipulating elk habitat quality. The failure of the cover/forage curve to demonstrate equal power cannot be viewed as sufficient reason to reject the cover/forage concept. It would be somewhat surprising if a single simple function was able to account for changes in elk habitat requirements over the summer season. A more comprehensive model will be required to achieve adequate evaluation of cover and forage requirements that may change substantially between June and September.

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During the summers of 1980 and 1981, field tests of elk/timber coordination guidelines were conducted on 11 study areas in Montana and northern Idaho. Evaluations of elk habitat based on different combinations of cover/forage functions and road models were compared to pellet group distributions. Elk response to variations in habitat quality was primarily determined by road densities. Acceptable road models predict over 50 percent of the variation in habitat use by elk.

KEYWORDS: elk, timber, habitat quality, cover/forage, roads

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